InP Etching for Resonant Enhanced Modulator Development

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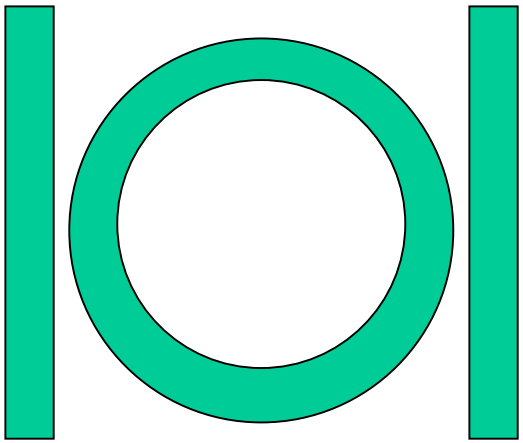
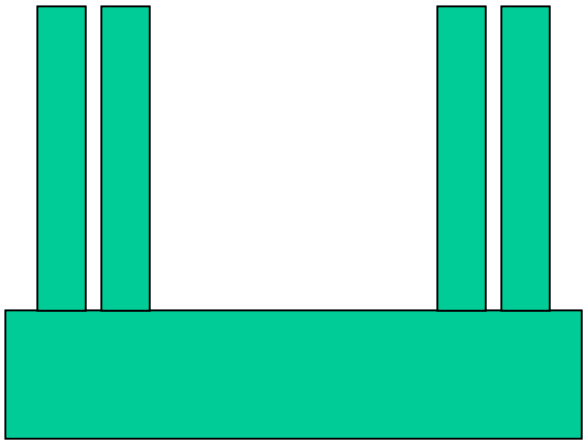
InP-based Resonant Enhanced Modulators





- Microring Resonators with a narrow airgap on the order of 100 nm
- Requires a structure with high edge acuity

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Adesida Group Overview

Leader: Prof. Ilesanmi Adesida, Director of the CCSM

Graduate Research Assistants: 8

Postdoctoral Research Associates: 5

Research Thrusts and Interests:

- High Speed InP circuits
- High Power GaN Devices and Circuits
- Advanced InP processing
- Advanced GaN processing
- Optoelectronic Devices, Circuits, and Receivers

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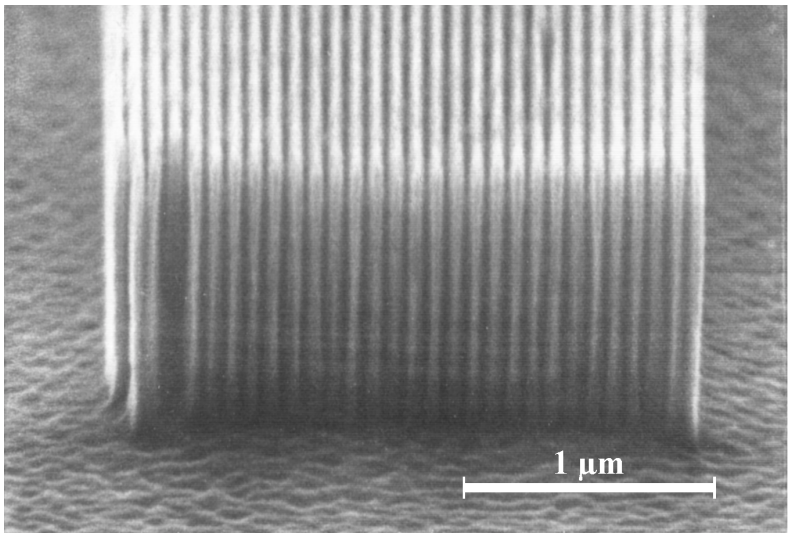
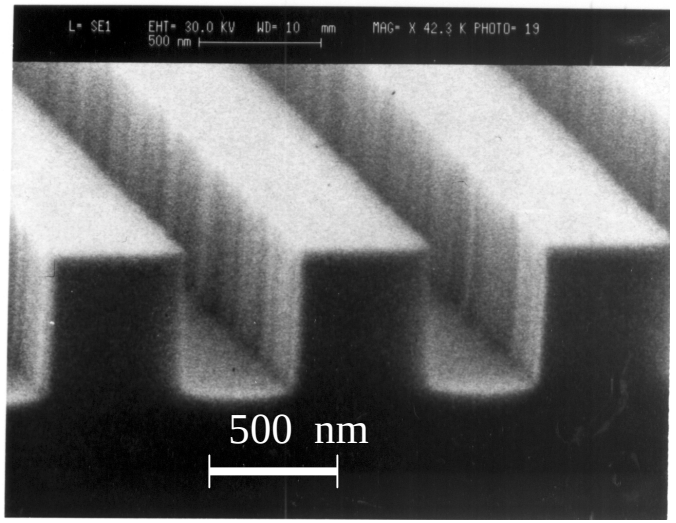
RIE Etching of InP at UIUC

I. Adesida, *et al.*, J. Vac. Sci. Tech. B, Vol. 8, pp. 1357-1360, 1990





- Etched with multiple steps of a CH_4/H_2 RIE etch followed by an O_2 clean for the removal of polymer buildup.
- 33 nm/min etch rate
- Highly anisotropic 35 nm wide wires at 70 nm pitch etched 300 nm deep were realized.

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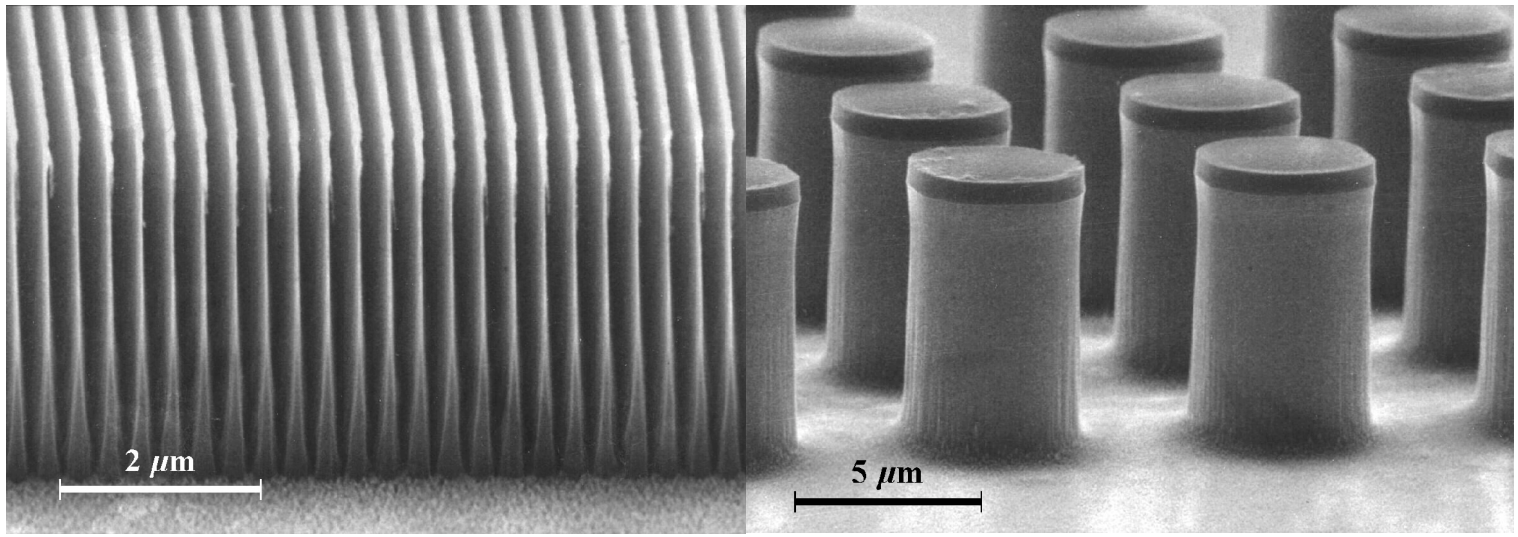
CAIBE Etching of InP at UIUC

C. Youtsey, *et al.*, J. Vac. Sci. Tech. B, **Vol. 12**, pp. 3317-3321, 1994



- Etched with an Ar ion beam and a Cl_2 ambient.
- Surface roughness was minimized by elevating the temperature above 150°C.
- Anisotropy was improved by etching above 225°C.
- At elevated temperature (250°C) an etch rate in excess of 2 μm/min was obtained.

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References of InP Etching at UIUC

RIE

- E. Andideh, *et al.*, J. Vac. Sci. Tech. B, **Vol. 7**, pp. 1841-1845, 1989
- I. Adesida , *et al.*, Inst. Phys. Conf. Ser., **Vol. B 7**, p. 425, 1989
- I. Adesida, *et al.*, J. Vac. Sci. Tech. B, **Vol. 8**, pp. 1357-1360, 1990

CAIBE

- C. Youtsey, *et al.*, J. Vac. Sci. Tech. B, **Vol. 12**, pp. 3317-3321, 1994
- C. Youtsey, *et al.*, J. Vac. Sci. Tech. B, **Vol. 13**, pp. 2360-2365, 1995
- R. Panepucci, *et al.*, J. Vac. Sci. Tech. B, **Vol. 13**, pp. 2752-2756, 1995
- R. Panepucci, *et al.*, J. Vac. Sci. Tech. B, **Vol. 14**, pp. 3641-3645, 1996
- C. Youtsey, *et al.*, J. Vac. Sci. Tech. B, **Vol. 14**, pp. 4091-4095, 1996

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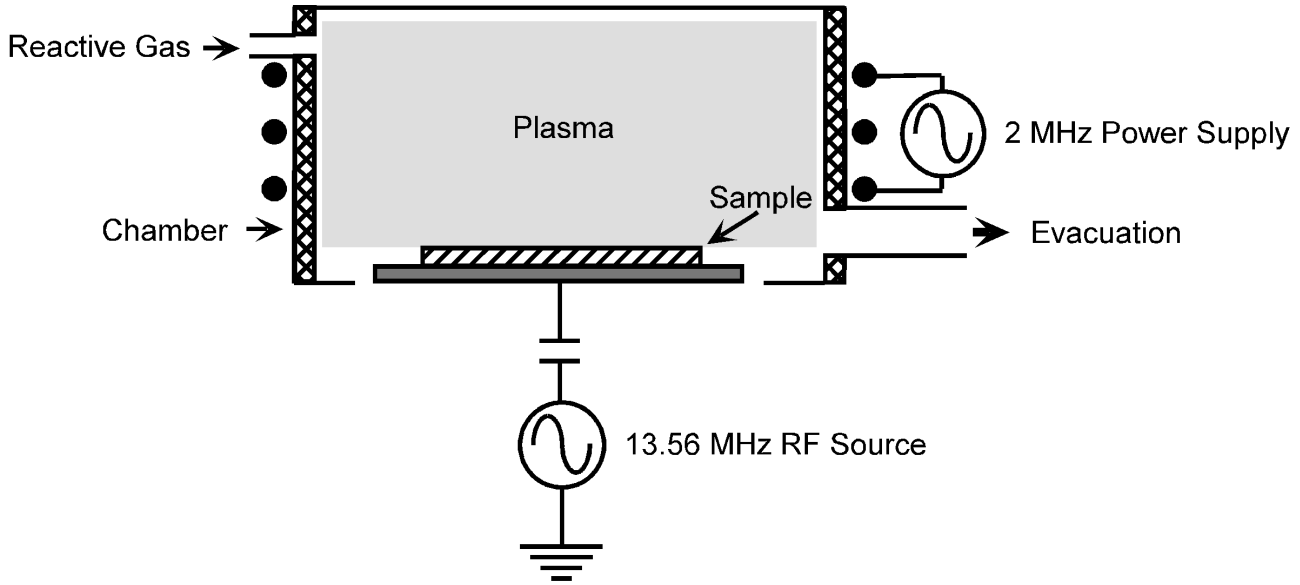
Inductively Coupled Plasma Reactive Ion Etching (ICP-RIE)



- RF current supplied through windings around the chamber induce a plasma with a density ($1x10^{11}$-$1x10^{12}$ ions/cm^{-3}) 2-3 orders of magnitude higher than RIE.
- Ion energy may be independently varied by superimposing an RF Bias.
- May be run at lower pressures than conventional RIE (<10 mT) to minimize undercut.
- High ion flux with low energies enables low etch damage while maintaining high etch rates

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Foreseen Challenges to Overcome

- The biggest challenge in realizing etched microstructures will be obtaining damage free surfaces.
  - Sidewall roughness/striations
  - surface roughness ("grass")
- To overcome these problems, we will pursue the following general paths:

  a) Alternate masking materials (SiN_x, SiO_2/Cr,Ti/Ni, etc.) and thicknesses

  b) Variations to the etch chemistry (addition of H_2 and N_2)

  c) Elevated substrate temperature to increase the volatility of etch products

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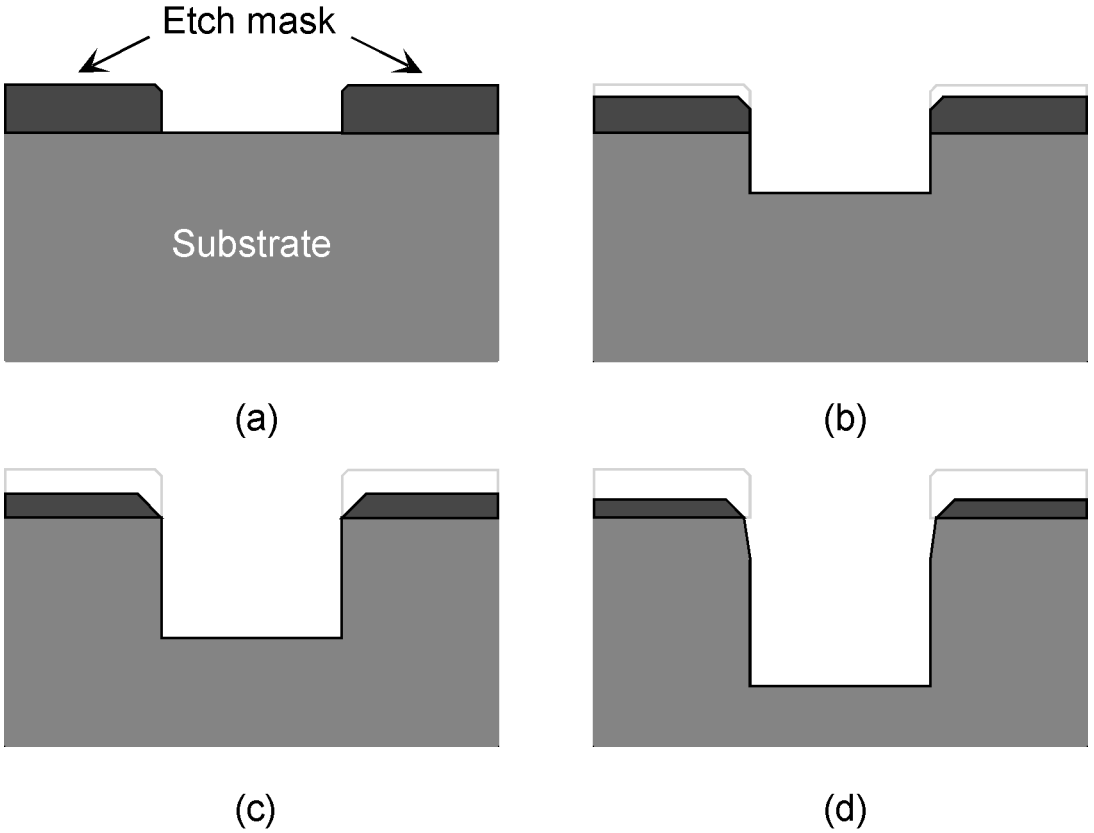
Mask Erosion



To avoid the effects of mask erosion there are two approaches:

- use of an alternate masking material with improved selectivity
- augmenting the thickness of the mask

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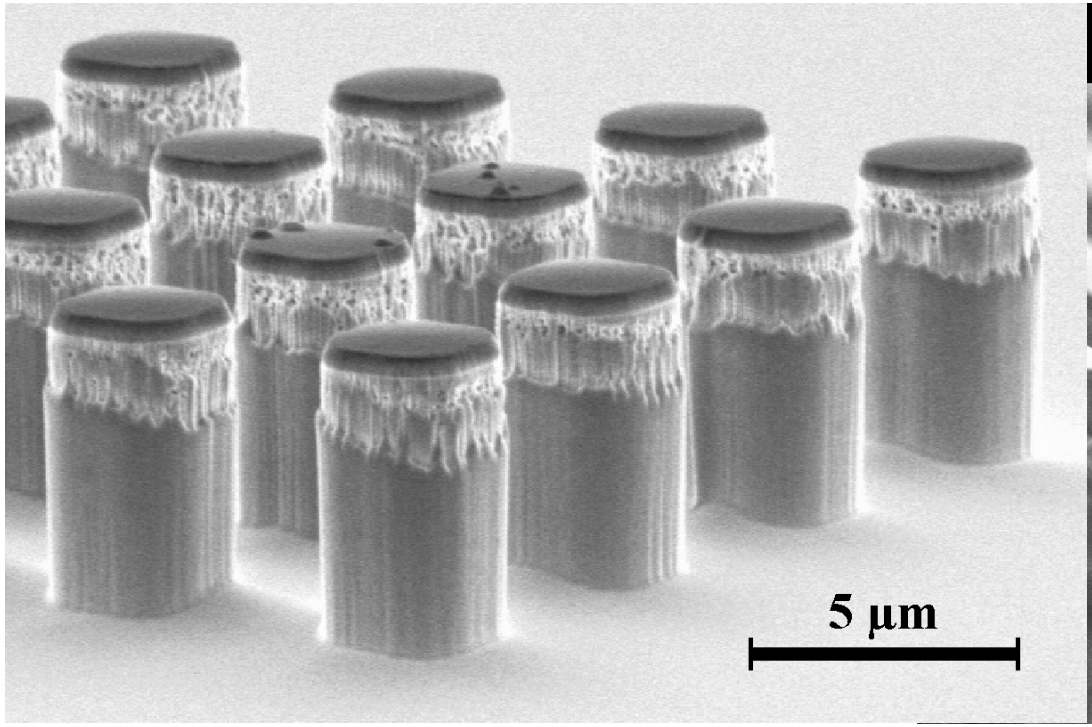
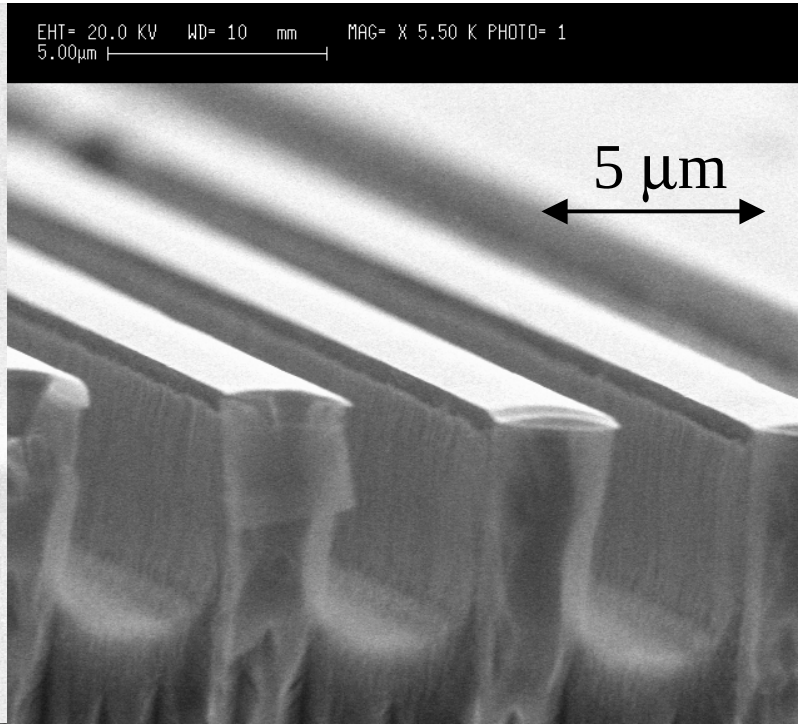
Mask Erosion





In the above pictures, the mask has begun to deteriorate. Note that while the top of the mesas are rough, the bottom portion remains smooth.

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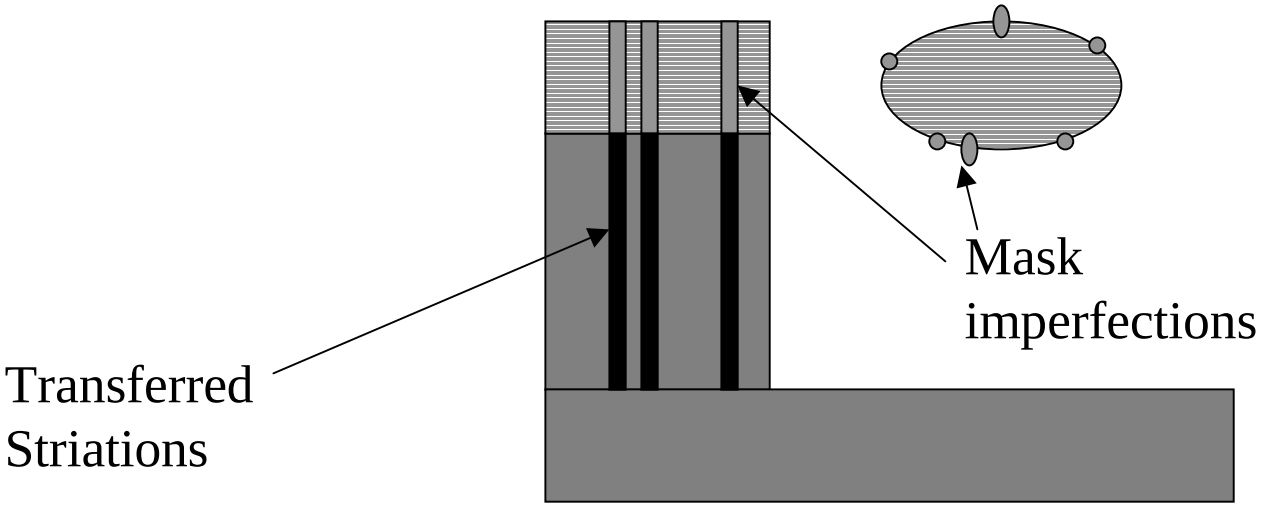
The "Shower Curtain" Effect



Striations in the sidewall profile are often attributed to existing imperfections in the masking material. The transfer of these striations is known as the "shower curtain" effect.

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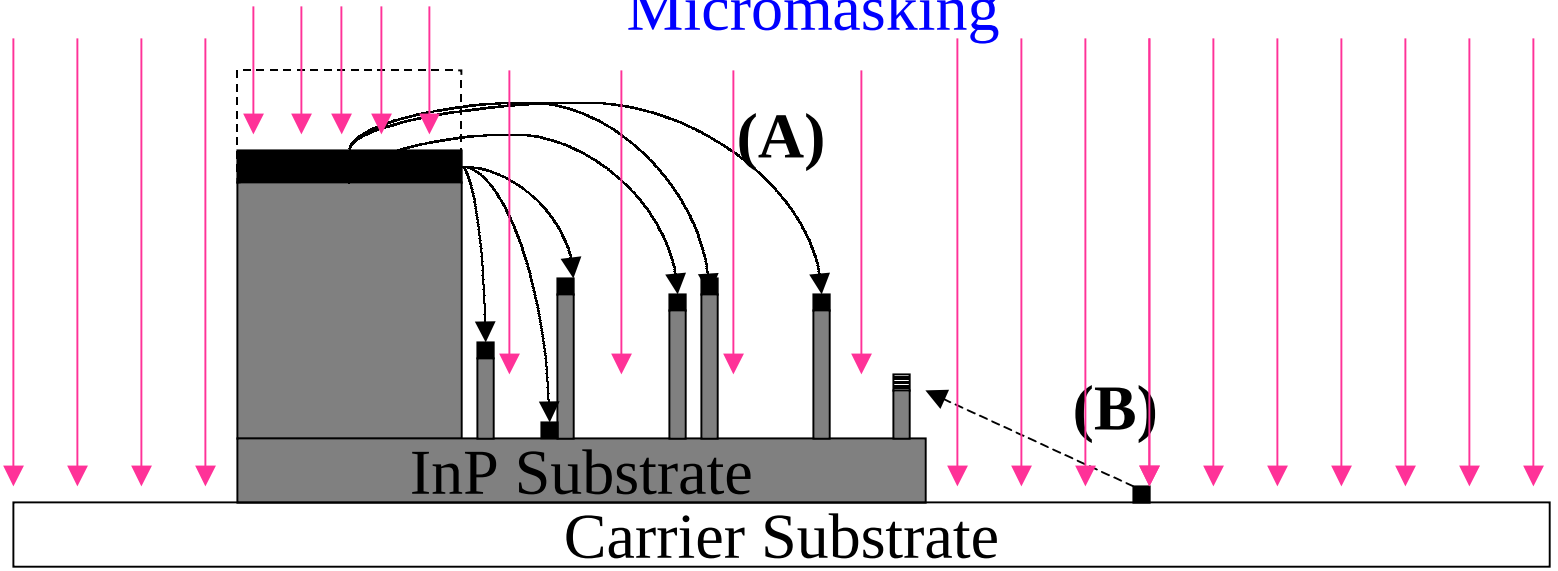
Micromasking



During etching, a phenomenon known as micromasking may lead to the formation of undesirable “grasslike” structures. The source of micromasking is commonly attributed to be:

- sputtered etch mask materials (A)
- sputtered material from the carrier substrate (B)

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InP-Based Etching for Resonant Enhanced Modulator Development

OBJECTIVES

- Micro-optical Process Development
  - Dry Etching Recipes for InP systems
  - Lithography of dimensions less than 1 μm linewidth with sharp edge acuity
- Device Design and Layout
- Device Processing

APPROACH

- Optimization of the ICP process
- Pattern Definition via E-beam lithography
- Profile Characterization via SEM and AFM

ACCOMPLISHMENTS

- Demonstration of a room temperature ICP-RIE process capable of etching at rates on the order of 1 μm/min.
- Improved anisotropy and surface roughness with variations in etching conditions

PLANS

- Detailed Studies of InP etching via a Cl_2/Ar Chemistry in an ICP-RIE
- Investigation of alternate masking materials
- Investigation of modified etch chemistries
- Demonstration of a laterally coupled ring resonator structure by Oct. 2000.

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Conclusions

- Goal of this research effort is to realize microring resonator structures in InP with sharp edge acuity and sub-micron linewidths.
- The structures will be defined in an ICP-RIE because the elevated plasma density and lower etch damage relative to CAIBE or RIE.
- Initial etch studies have been initiated and will be detailed in the closed meeting